HANDCRAFTED APPROACHES FOR CONTACTLESS 3D HUMAN BIOMETRIC IMAGE RECONSTRUCTION FOR SECURED IDENTIFICATION.

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Introduction:

The need for strong biometric authentication systems has increased due to growing worries about identity theft and digital security. Conventional techniques like iris detection, fingerprint scanning, and facial identification have drawbacks such exposure to light, changes in expression, wear, and specialist equipment. Alternative biometric characteristics, such as finger knuckle prints (FKPs), which gets less abraded provides distinctive, stable structural patterns that are difficult to duplicate, and are being investigated by researchers in order to overcome these difficulties.

Compared to fingerprints or facial features,3D FKP images are less vulnerable to spoofing and environmental deterioration. However, the majority of the images used by current systems are 2D, which lacks depth and may overlook finer features, resulting in errors in feature extraction and matching. In order to increase security and accuracy, our work presents a 3D reconstruction method for finger knuckle authentication.

The procedure entails gathering 3D FKP images from publicly available datasets and then performing preprocessing operations includes noise reduction. A gradient-based method called the Frankot-Chellappa algorithm is used to estimate surface depth while preserving integrability in order to transform 2D multiple images into 3D models. To enhance the reconstructed model, Gaussian and Wiener filters are applied, and their effectiveness is evaluated using statistical metrics—Mean Absolute Error (MAE) and Mean Square Error (MSE) to assess performance. The comparative analysis reveals that the Gaussian filter achieves the lowest error values compared to Weiner, indicating superior performance in preserving biometric details while reducing noise. The proposed 3D reconstruction approach further strengthens finger knuckle identification, enhancing its potential for real-world security and authentication systems.

Objectives:

1. Image Capture To guarantee high-quality input for processing, gather crisp 2D pictures of finger knuckle prints.

2. 3D Model Creation: Use the Frankot-Chellappa technique to convert 2D photos into 3D models, capturing distinctive traits for precise identification.

3. Performance Evaluation: To verify increases in biometric reliability, test the 3D models' precision, effectiveness, and security.

Methodology:

Io facilitate the development of biometric systems, Hong Kong Polytechnic University's 3D FKP Dataset offers textured, depth-rich models for finger knuckle recognition. It is frequently used to capture 2D images from several angles.

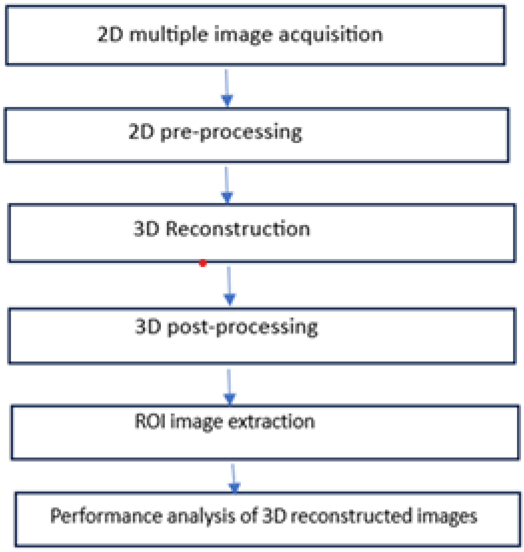

Fig. 1. Block diagram of 3D Image Reconstruction

2D multiple images acquisition:

High-resolution, multi-angle photos taken in regulated lighting conditions using visible and infrared light are available in the 3D FKP dataset from Hong Kong Polytechnic University, for precise 3D reconstruction and biometric analysis.

Pre-processing:

A Gaussian filter smoothes the image and lowers noise while maintaining important characteristics during preprocessing. For precise 3D reconstruction, it improves consistency, normalizes lighting, and boosts contrast.

3D Reconstruction:

To create a comprehensive knuckle model, 3D reconstruction employs six 2D pictures and integrates SfM, stereo imaging, and deep learning. Then, using picture gradients, the Frankot-Chellappa algorithm generates a 3D height map.

Post- processing:

The Inverse Fourier Transform is used to create the 3D height map. Gaussian and Wiener post-processing improves detail, lowers noise, and guarantees precise 3D models for biometric applications.

Performance analysis:

To ensure accurate 3D reconstruction, performance is evaluated using statistical metrics like MAE and MSE. MAE shows average prediction error, while MSE highlights larger deviations. These metrics help assess accuracy and improve model reliability for biometric use.

Result and Conclusion:

A comparative analysis of 3D original, Gaussian-filtered, and Wiener-filtered images is done using MAE and MSE. The Gaussian filter achieved the lowest MAE, showing better noise reduction and detail preservation. Though both filters introduced slight distortions, the Gaussian filter maintained better depth consistency, making it more effective for accurate 3D reconstruction.

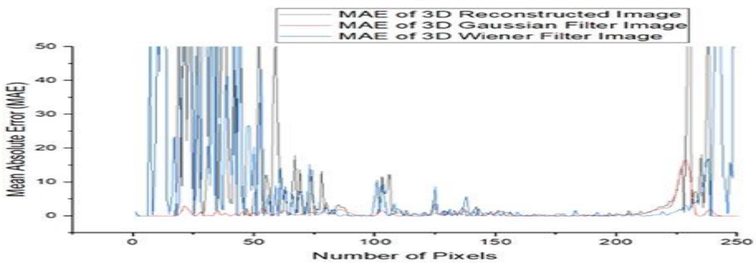

Fig 2: Comparison of Mean Absolute Error (MAE) Values for 3D Reconstructed image, 3D Gaussian and Wiener filtered image.

The Gaussian filter outperforms the Wiener filter in terms of noise reduction and feature preservation, yielding the lowest MSE. It is perfect for biometric application since it guarantees better 3D reconstruction quality.

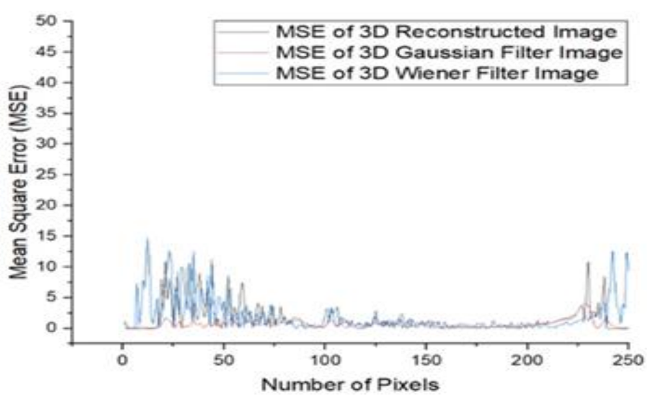

Fig.3: Comparison of Mean Square Error (MSE) Values for in 3D Reconstructed image, 3D Gaussian filter image and 3D Wiener filter image

Conclusion:

The usefulness of contactless 3D finger knuckle biometrics for safe authentication is demonstrated in this study. By using an organized process of 2D pre-processing, 3D reconstruction, and post-processing, we have shown the importance of sophisticated filtering methods—particularly the Gaussian filter—in enhancing the quality and accuracy of 3D models. The Gaussian filter is a vital tool for reducing noise while preserving the integrity of biometric data, as it smooths the image without compromising critical features. Compared to the Wiener filter, the Gaussian filter produced better performance in terms of accuracy and noise suppression. The parametric analysis emphasizes the need to balance computational efficiency, feature retention, and noise reduction to achieve optimal performance. Overall, the results underline the potential of 3D finger knuckle biometrics as a robust and reliable solution for digital security applications, with filtering strategies playing a key role in its effectiveness.

Future Scope:

1. A variety of filters, including the Median Filter for eliminating impulsive noise, the Bilateral Filter for edge-preserving smoothing, and the Sobel Filter for identifying edges and gradients, can be used to improve image quality and feature extraction.

2. To assess the quality and consistency of 3D reconstructed data, a number of statistical characteristics can be used, including mean, median, mode, variance, quartiles, skewness, and kurtosis.